PHYTOPLANKTON OF AN INSHORE AREA OF GEORGIAN BAY OF LAKE HURON PRIOR TO REDUCTIONS IN PHOSPHORUS LOADING FROM LOCAL SEWAGE TREATMENT FACILITIES

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PHYTOPLANKTON OF AN INSHORE AREA

OF

GEORGIAN BAY OF LAKE HURON PRIOR TO REDUCTIONS IN

PHOSPHORUS LOADING FROM LOCAL SEWAGE TREATMENT FACILITIES

A report prepared in conjunction with the
International Joint Commission's Project D-5
on the Upper Great Lakes

by

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1975

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ABSTRACT

The phytoplankton of an inshore area of Georgian Bay, Lake Huron affected by artificial inputs of nutrients in treated sewage effluents from local municipalities was studied during the ice-free periods of 1973 and 1974. The data have been gathered as essential background information prior to implementation of a sewage phosphorus removal programme in 1974-75.

Total biomass of phytoplankton ranged from an ice-free period mean of 1.17 mm^3/l at Station PM2 off Port McNicoll to 7.37 mm^3/l in Penetang Bay. Standing crops of phytoplankton were consistently high throughout the ice-free period only in Penetang Bay while large seasonal changes occurred at the other sampling locations.

Differences in seasonal distribution of total biomass and to some extent species composition in the inshore Georgian Bay areas are likely related to both turbulent mixing and interaction with aquatic macrophyte communities as well as to rates of nutrient supply.

Diatoms (Bacillariophyceae) were most important (by volume) throughout the study area being represented mainly by Stephanodiscus astraea, S. invisitatus, Fragilaria crotonensis, F. capucina, Asterionella formosa, Tabellaria fenestrata and Rhizosolena longiseta.

Although high densities of blue-green "bloom-forming" phytoplankton were present on occasion in Penetang Bay, this group was never of great significance at the inshore sampling locations probably owing to the lack of stable thermal stratification. The cryptomonad Cryptomonas erosa was very abundant in Penetang Bay and comprised between 20 and 60 percent of total phytoplankton biomass throughout most of the ice-free periods of both years.

The importance of at least two years concurrent observations is emphasized by the large year-to-year differences in species distribution.

Despite evidence of nitrogen limitation of phytoplankton in Penetang Bay, it is suggested that phosphorus will quickly become the controlling factor following phosphorus removal from sewage discharges. Other predictions for the future include the probable absence of blooms

of *Ceratium hirundinella*, *Anabaena limnetica* and *Aphanizomenon flos-aquae* which have characterized Penetang Bay during 1969, 1973 and 1974. Additionally, certain Chrysophyceae which were more prevalent at the Georgian Bay inshore areas, less enriched than Penetang Bay, may become more important in Penetang Bay in the future.

INTRODUCTION

The phytoplankton of Georgian Bay of Lake Huron had been virtually unstudied prior to the investigations of Veal and Michalski (1971), while the phytoplankton of the adjacent open waters of Lake Huron has been little known until only recently (Parkos et al., 1969; Schelske and Roth, 1973; Schelske et al., 1974; Vollenweider et al., 1974; Davis et al., 1975; and Stoermer et al., 1975).

The rationale and objectives of the present study of an inshore area of Georgian Bay have been given by Veal and Michalski (1971) and Robinson (1975). This paper reports on results of phytoplankton investigations conducted during 1973 and 1974. Complementary physical-chemical data collected during the same period have been summarized by Robinson (1975). The data are meant for comparative purposes relative to similar, continuing investigations in the study area and can be considered as essential background information prior to implementation of a phosphorus removal programme (1974-75) at local municipal sewage works discharging treated sewage to Midland and Penetang Bays and adjacent inshore areas of Georgian Bay (Figure 1).

METHODS

Phytoplankton was collected biweekly from May through October of 1973 and 1974 as composite samples through the euphotic zone by allowing a weighted one litre bottle with a restricted inlet to fill as it was lowered and raised through a depth corresponding to twice the Secchi disc visibility. Samples for chlorophyll and nutrient analyses were collected in the same manner (Robinson 1975). The samples were immediately fixed with Lugols solution and transported to the Ministry laboratory in Toronto where the phytoplankton was concentrated by sedimentation. Counting was done at 600X with an inverted microscope and results were expressed as total cell volume. Diatom samples were ashed (Weber 1971) and mounted in Hyrax for identification (phase contrast at 1500X) and enumeration. Taxonomic references included Huber-Pestalozzi (1938, 1941, 1942, 1955, 1961, and 1968), Bourrelly (1966, 1967, 1970) Starmach (1966), Sieminska (1964), Prescott (1951), Skuja (1948) and Patrick and Reimer (1966).

RESULTS AND DISCUSSION

I Phytoplankton - spatial differences and seasonal changes

(a) Concentration

Highest phytoplankton densities occurred in Penetang Bay at Station P1 with ice-free period mean biomass values of 7.37 and 5.12 mm^3/l during 1973 and 1974, respectively. The lowest mean value was found at Station PM2 off Port McNicoll during 1973 (1.17 mm^3/l) while the 1974 mean biomass at the same location was about twice as high at 2.55 mm^3/l (Figure 2). Concentrations were also low (relative to those at P1) in Sturgeon Bay at Station BS with ice-free period mean values during 1973 and 1974 of 1.83 and 1.34 mm^3/l, respectively. Results from the more northerly sampling location (Station P4) and from Midland Bay (Station M1) were very similar (Figure 2) with mean values at P4 of 2.43 and 2.72 and at M1 of 2.24 and 2.84 mm^3/l during 1973 and 1974, respectively. The combined 1973-74 mean biomass in Penetang Bay was significantly greater (statistically, $P < 0.005$) than those of the other four locations, while results from the outer, northerly sampling location (P4) were not significantly different ($P < 0.05$) from Stations BS, PM2 or M1.

Results from the same locations as sampled in 1969 (Veal and Michalski 1971) showed a similar spatial distribution of phytoplankton densities with highest values in nutrient enriched Penetang Bay and lowest values at the shallow, weedy BS sampling location.[1]

Considerable differences exist between the phytoplankton biomass of inshore regions of the present study area and the open waters of Lake Huron. For example, the mean biomass in Penetang Bay during 1973 was approximately 8 times greater than the mean phytoplankton biomass (0.9 mg/l) during the ice-free period of 1971 at an off-shore location of Lake Huron (Vollenweider et al., 1974). Differences in phytoplankton biomass between inshore and offshore waters of Lake Michigan (Holland and Beeton, 1972) and Lake Ontario (Munawar et al., 1974) have also

[1]Footnote: Results of the earlier investigation are not directly comparable since phytoplankton density was expressed as areal standard units/ml.

been documented with generally greater inshore biomass resulting primarily from the stimulatory effects of nutrient enrichment and warmer inshore surface water temperatures. The phytoplankton densities in the Penetang Bay area of Georgian Bay are comparable with those recorded from decidedly eutrophic areas of the Great Lakes such as Saginaw Bay of Lake Huron and Lake Erie's Western Basin (Table 1).

Seasonal changes in total phytoplankton biomass were quite variable between the two years of the study. Only the outer northern-most station (P4) and the Midland Bay (M1) location showed a bimodal distribution of phytoplankton with substantially higher phytoplankton densities in spring and fall than in mid-summer during both years of the study (Figure 3, Appendix 1). A bimodal distribution of phytoplankton was present in Penetang Bay during 1973 but densities were consistently high throughout the ice-free period of 1974 (Figure 3). Sturgeon Bay phytoplankton (where mean values were lowest) showed highest values during early summer and no tendency to peak in spring or fall (Appendix 1).

Davis (1964) has shown that a change from bimodal distributions of phytoplankton to more uniform seasonal distributions including mid-summer maxima characterized the eutrophication process in Lake Erie's Western Basin between 1919 and 1963. Differences in seasonal distribution of total biomass in the shallow Georgian Bay inshore areas are likely related to both turbulent mixing and interaction with aquatic macrophyte communities as well as to rates of nutrient supply, and conclusions regarding trophic status based solely on seasonal distribution of total biomass are probably not applicable to much of the Georgian Bay inshore area.

(b) Composition

Diatoms (Bacillariophyceae) were most abundant (by volume) throughout the study area and showed little year-to-year variation in their percentage contribution to the total phytoplankton composition at most locations (Figures 2 and 3; Appendix 1). A noteworthy difference existed between 1973 and 1974 only at the Port McNicoll station (PM2) where diatoms comprised 42% of the mean 1973 biomass, but 71% during 1974 owing primarily to the development of a springtime maximum of Rhizosolenia longiseta (4.12 mm^3/l) which did not materialize during the spring of 1973 (Figure 3). Cyanophyceae (mainly Anabaena limnetica and Aphanizomenon

TABLE 1: Comparative phytoplankton biomass* at several Great Lakes sampling locations.

	Phytoplankton biomass (mm^3/l or mg/l)		
	Mean	Range	Reference
Lake Ontario			
inshore	3.3	0.8 - 7.4	Vollenweider *et al*
offshore	2.6	0.6 - 9.0	" (1974)
Lake Erie			
Western Basin	5.3	0.8 - 13.2	"
Central Basin	3.2	0.6 - 6.0	"
Eastern Basin	2.4	1.0 - 4.2	"
Lake Huron			
mid-lake	0.9	0.3 - 1.8	"
Saginaw Bay	8.3	1.6 - 17.3	"
Georgian Bay			
P1	6.25	1.75 - 31.5	present study
P4	2.57	0.33 - 8.78	" "
M1	2.54	0.33 - 9.04	" "
PM2	1.86	0.51 - 5.47	" "
BS	1.59	0.32 - 4.69	" "

*Lakes with phytoplankton densities less than 1 mm^3/l are usually clear water lakes with transparencies (Secchi disc visibilities) greater than 5 m. Phytoplankton densities greater than 20 mm^3/l are usually associated with very turbid waters having transparencies less than 1 m.

flos-aquae) were more abundant during 1973 at this location than during 1974 with ice-free period mean concentrations of 0.25 mg/l and 0.03 mg/l during 1973 and 1974, respectively. The phytoplankton composition was remarkably similar during 1973 and 1974 at Stations P4, M1 and BS. Sturgeon Bay (BS), however, exhibited a more equal representation of all classes of algae (Figure 2). The Chrysophyceae especially were more abundant in Sturgeon Bay than at the other inshore locations owing mainly to the presence of Dinobryon sociale v. americanum (Figure 4). Cyanophyceae (mainly Anabaena limnetica and Aphanizomenon flos-aquae) were better represented, relative to the other algal classes, in Sturgeon Bay than elsewhere.

Although high densities of blue-green "bloom-forming" phytoplankton were present on occasion in Penetang Bay (for example 0.44 mm^3/l of A. limnetica on August 27, 1974), this group was never of great significance at this location (Figures 3 and 5). Gravenhurst Bay of Lake Muskoka initially with similar mineral and nutrient characteristics, was dominated by the cyanophytes Aphanizomenon flos-aquae and Anabaena flos-aquae and densities of these species decreased dramatically following decreased loadings of P to the Bay (Michalski and Nicholls, 1975). It is not readily apparent why Cyanophyceae are not much more abundant in Penetang Bay since the group is notoriously present in the plankton of nutrient enriched portions of the Great Lakes during summer (Vollenweider et al., 1974; Schelske and Roth, 1973). The relative scarcity of members of this class in Penetang Bay may in part be related to the absence of stable thermal stratification (Lund, 1965). The generally well mixed water column in Penetang Bay probably ensures availability of adequate carbon dioxide for photosynthetic uptake by diatoms, cryptomonads and dinoflagellates which are able to outcompete the blue-green algae. Although Sturgeon Bay is very shallow and also well mixed, the photosynthetic uptake of free carbon dioxide by the abundant macrophyte growths probably has allowed cyanophytes to be favoured at certain times over other algae in Sturgeon Bay owing to their greater ability to utilize bicarbonate as a carbon source (Shapiro 1973; James and Lee 1974). The pH data (Robinson, 1975) do in fact substantiate this argument with mean and maximum euphotic zone values in Penetang Bay of 7.6 and 8.2, while mean and maximum pH values in Sturgeon Bay were 7.9 and 9.0, respectively.

Aside from the differences in total phytoplankton density, the only notable difference between the outer station (P4) and the Penetang Bay station (P1) relates to the much greater importance of cryptomonads at P1 (Figure 3). At both locations, diatoms were dominant during spring and fall with the mid-summer period dominated by cryptomonads and dinoflagellates, especially in Penetang Bay. Green algae, chrysophytes and blue-green algae were represented in lesser quantities throughout the ice-free period with only the blue-greens showing consistent seasonal tendencies with peaks in mid to late summer (Figure 3).

Several species of cryptomonads were found throughout the study area (Appendix 2) but only Rhodomonas minuta (mainly var. nannoplanctica) and Cryptomonas erosa were quantitatively important. Penetang Bay contained densities of C. erosa approaching 4 mm^3/l on occasion (Figure 5) and comprised between 20 and 60% of total phytoplankton biomass through most of the ice-free periods. R. minuta var. nannoplanctica was restricted mainly to the spring and early summer periods of both years (Figure 5). Cryptomonas platyuris was much more abundant in Penetang Bay than at the other inshore Georgian Bay sampling sites. Eutrophic lakes in Sweden (Ahlgren, 1970; Nauwerck, 1963) contain high densities of these and other cryptomonads and when represented by high numbers, the Cryptomonas-Rhodomonas group is undoubtedly a good indication of nutrient enriched waters.

During the second week of September of 1973, an extremely high density (28.9 mm^3/l) of the dinoflagellate Ceratium hirundinella was found in Penetang Bay, having increased from 0.51 mm^3/l recorded two weeks earlier. Maximum concentrations of this organism were always less than 1 mm^3/l at the other Georgian Bay sampling locations with the exception of Stations P4 and BS where biomass reached 2.30 and 1.52 mm^3/l respectively, on one occasion during 1973. Explosive growth leading to high densities of C. hirundinella has been documented for other eutrophic waters (Duthie and Kirton 1970; Talling 1971; Michalski and Nicholls, 1975; Kling, 1975). Other recorded Dinophyceae included several species of Peridinium, Glenodinium and Gymnodinium; however, little can be concluded pertaining to their variable distribution in the Georgian Bay inshore area (Appendix 2). It is well known that several dinoflagellates have specific needs for light and temperature (Berman and Rodhe, 1971; Pechlaner 1971) and species which are restricted by shallow water depth from carrying out daily vertical migrations to satisfy optimum light

requirements are not likely to be found in shallow waters (Nicholls, 1975) and may partially explain the absence of species such as Peridinium wisconsinense and Gymnodinium helveticum (Appendix 2) from the Sturgeon Bay sampling location.

Of the diatoms, Stephanodiscus astraea and Fragilaria crotonensis were quantitatively most important, with strong representation in Penetang Bay (Figures 4 and 6). It is noteworthy that F. crotonensis has become a dominant diatom in the plankton of Lake Mjösa as a result of eutrophication of the lake (Skulberg, 1974). F. crotonensis in Georgian Bay was most prominent during spring and early summer and, while the seasonal distribution of Stephanodiscus astraea was not as well-defined, S. invisitatus was common during the spring and fall of 1973 at all locations except Sturgeon Bay (Figure 4). Relatively high autumn densities of S. invisitatus during 1974 were found only in Penetang Bay and its absence from the other sampling locations may have been precluded by a more rapid increase of Fragilaria capucina (Figure 6).

Asterionella formosa was also a spring and early summer species and was more abundant in Penetang Bay than elsewhere during periods favourable for growth (Figure 6). Melosira granulata and M. ambigua (two well known indicators of eutrophy) were also important in the Georgian Bay inshore areas, but mainly during the summer period. Another large diatom of importance in considerations of total biomass was Tabellaria fenestrata which, like S. astraea, was irregular in its seasonal distribution (Figure 6); but again, year-to-year differences were significant and reasons for much higher concentrations of this organism during 1974 over 1973, especially in Penetang Bay and at the Port McNicoll station, are not apparent.

The importance of two years concurrent observations has particular significance with regard to the distribution of Rhizosolenia spp. Both R. eriensis and R. longiseta are well known from the Great Lakes but R. eriensis is generally considered an oligotrophic species while R. longiseta is an indicator of more eutrophic waters (Mayhew et al, 1974). In Georgian Bay, R. longiseta was very abundant during the spring of 1974 (as high as 5.4 mm^3/l at the Midland Bay location) but virtually absent during 1973 (Figure 4) when R. eriensis was prominent. Much lower densities of R. eriensis appeared during 1974 following the springtime pulse of R. longiseta (Figure 4). It would appear that Rhizosolenia

species in Georgian Bay may have similar requirements for growth but maximum biomass of the genus is not achieved through co-development of the two species but rather when one species either outcompetes or inhibits the other (Figure 7).

Estimates of primary production are not available from 1973 or 1974, but phytoplankton samples from 4th of September, 1969, when primary production data are available (Veal and Michalski 1971) were re-analyzed to express biomass as total cell volume. The resulting production per unit biomass values ("activity coefficients" of Rodhe et al, 1958) calculated from the 1969 data are surprisingly high (Table 2; see also data reviewed by Findenegg, 1965) in view of the relatively low incident radiation intensity at this time of year and the domination of the phytoplankton by large diatoms and dinoflagellates (mainly Melosira spp. and Glenodinium and Peridinium spp.). It is noteworthy that production per unit biomass was somewhat greater at the Midland Bay station and may have been related to greater representation by Chlorophyceae (approximately 15% of total biomass) than at the other sampling locations where contributions by Chlorophyceae ranged from one to four percent only. It is widely accepted that nannoplankters have a higher production efficiency than larger forms - "the best effect of relative production is found when Chlorococcales.....prevail in the phytoplankton" (Findenegg, 1965). In this regard, phytoplankton production per unit biomass during 1973 and 1974 was likely significantly greater in Penetang Bay where small cryptomonads were especially more abundant than at the other Georgian Bay locations.

II Nutrient considerations and predictions of changes in the Phytoplankton of Penetang Bay following decreased P loading.

Problems related to development of lake classification and trophic status indices have been reviewed by Vollenweider (1968). Attempts to rank or characterize Great Lakes waters with respect to trophic status are particularly difficult owing primarily to localized areas of the Great Lakes characterized by relatively recent artificial nutrient enrichment (Vollenweider et al., 1974). Dobson et al (1974) have provided a preliminary trophic status ranking of Great Lakes waters based on Secchi disc and chlorophyll a measurements. Vollenweider et al (1974) have categorized the trophic status of the Great Lakes utilizing phytoplankton

TABLE 2: Rates of carbon assimilation at optimum depth (from Veal and Michalski, 1971), phytoplankton biomass and activity coefficients (production per unit biomass per day) on September 4, 1969 at four Georgian Bay inshore sampling locations.

Location	mg $C/m^3/day$	phytoplankton biomass (mg/m^3)	activity coefficient
Port McNicoll (PM2)	241	2840	0.085
Outer station (P4)	210	1770	0.119
Penetang Bay (P2)	509	4730	0.108
Midland Bay (M1)	268	1770	0.152

production and biomass data. Their scheme recognizes certain inshore and embayment areas of Lakes Erie, Ontario and Michigan as "secondary eutrophic" which they have defined as ".....regions showing relatively high annual primary production, occurrence of occasional algal blooms, and/or increased growth of periphyton (Cladophora) or macrophytes due to local pollution".

Our own experience relates more to small inland recreational lakes in Ontario, and based on Secchi disc and chlorophyll a data (Figure 8) and as well on phytoplankton biomass and species composition, Penetang Bay can be considered decidedly eutrophic. Using the same criteria, the other four inshore locations are likely mesotrophic however, Sturgeon Bay is probably more eutrophic than the phytoplankton data indicated owing to dense growths of aquatic macrophytes which were not investigated during this study.

It is generally recognized that artificially enriched waters tend to demonstrate N limitation of phytoplankton (Ambuhl, 1960; Ryther and Dunstan, 1971; Schindler et al., 1974, Nicholls, 1975; Michalski and Nicholls, 1975). Inorganic N was measured on four occasions during 1974 and was undetectable (<10 µg N/l) at all sampling locations during late September. At the other times, concentrations ranged from <10 µg N/l to 190 µg/l depending on the location. Sturgeon Bay consistently showed lowest values (probably as a result of aquatic macrophyte uptake) with a detectable amount (50 µg NO_3^- - N/l; 30 µg NH_4^+ - N/l) present only during the third week of May. Similarly, results from six samplings during the ice-free period of 1973, showed a range of inorganic N concentration from <10 to 200 µg N/l with concentrations near or below the lower limit of analytical detection frequently occurring at all locations. Sturgeon Bay again had the lowest concentrations of both NH_4^+ - N and NO_3^- - N. Further evidence for N limitation relates to low N/P ratios of 9.5, 11.1 and 11.1 during 1969, 1973 and 1974 respectively in Penetang Bay. Mean N/P ratios at other inshore Georgian Bay locations (Robinson, 1975) are probably indicative of P, rather than N limitation during most of the ice-free periods.

Although several other factors are instrumental, inorganic N availability is important in determining chlorophyll a content of phytoplankton (Nicholls, 1975) and it is perhaps significant that mean

chlorophyll a contents of phytoplankton (µg Chl a/µg phytoplankton fresh weight) during 1973 and 1974 were 26%, 30%, 41%, and 30% higher at P4, M1, PM2 and BS, respectively than in Penetang Bay (P1) and is additional evidence for N limitation of phytoplankton in Penetang Bay.

Of some predictive value, is a comparable study of Gravenhurst Bay of Lake Muskoka (Michalski and Nicholls, 1975) where hydrological and limnological features, similar to those of Penetang Bay, characterized Gravenhurst Bay prior to implementation of a P removal programme in 1971 at local sewage treatment works. The similarity of the two studies with respect to design and preliminary results of the investigation logically leads to predictions of changes in water quality in Penetang Bay following reductions in P loading. Clearly, any improvements in water quality relating to lower densities of phytoplankton and improved water clarity resulting from a decrease in P loading must depend upon the establishment of limiting concentrations of P, not N. Despite the above outlined indications of N limitation presently existing in Penetang Bay, it is suggested that P will quickly become the controlling factor in Penetang Bay following P removal from sewage discharges. N limited summer phytoplankton growth in Gravenhurst Bay prior to initiation of the P removal programme but mean ice-free period N/P ratios steadily and quickly rose from 12.4 in 1971 to 25.6 in 1974 (Michalski and Nicholls, 1975).

It has been shown (Schindler et al, 1974; Cheng and Taylor, 1973; Nicholls, in prep) that lakes differing only in mineral and nutrient chemistry but which are similar in morphometry and climatic location are often different in algal species composition and biomass. As well, the most dramatic change in Gravenhurst Bay of Lake Muskoka following reduced P loadings entailed a seven-fold decrease in the combined mean biomass values of Aphanizomenon flos-aquae and Anabaena flos-aquae. Other changes in species composition have been less well defined although an increase in the relative abundance of certain chrysophytes was noted (Michalski and Nicholls, 1975).

It is suggested that the most important changes in Penetang Bay phytoplankton following reduced P loadings will relate to trends towards lower densities of total phytoplankton and that major changes in species composition are unlikely. However, it is probable that blooms of Ceratium hirundinella, Cryptomanas erosa, Anabaena limnetica, A. spiroides and Aphanizomenon flos-aquae which have characterized Penetang Bay

during 1969, 1973 or 1974 will not occur after 1975. Additionally, there is particular interest in following the dynamics of organisms such as Cryptomonas platyuris and certain Peridiniales which have been mainly restricted to Penetang Bay. Certain Chrysophyceae such as Chrysococcus rufescens, Chrysolykos planctonicus, Chrysosphaerella longispina and several Dinobryon species, which were more prevalent at the Georgian Bay sampling locations, less enriched than Penetang Bay, may become more important in the plankton of Penetang Bay in future years.

Following the Gravenhurst Bay example, trends to: 1) higher inorganic N concentration, 2) higher total N:total P ratios, 3) lower total P concentrations and 4) improved water clarity should also begin in Penetang Bay in 1976. It is our intention to continue investigations in future years to document fully changes in the limnology of the Georgian Bay inshore area resulting from reduced P loading.

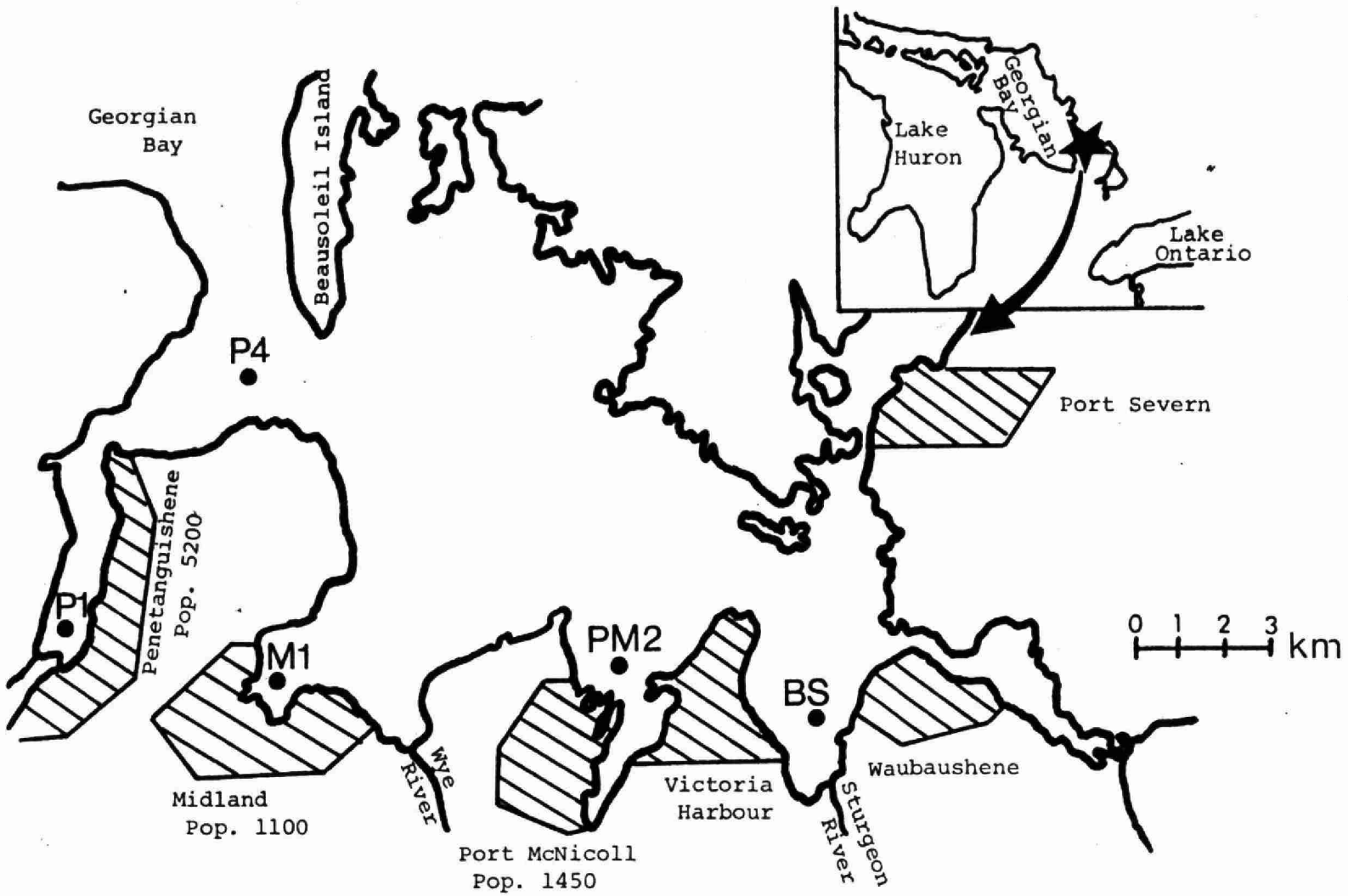

FIGURE 1: THE INSHORE AREA OF GEORGIAN BAY SHOWING LOCATIONS OF THE FIVE SAMPLING LOCATIONS FOR PHYTOPLANKTON.

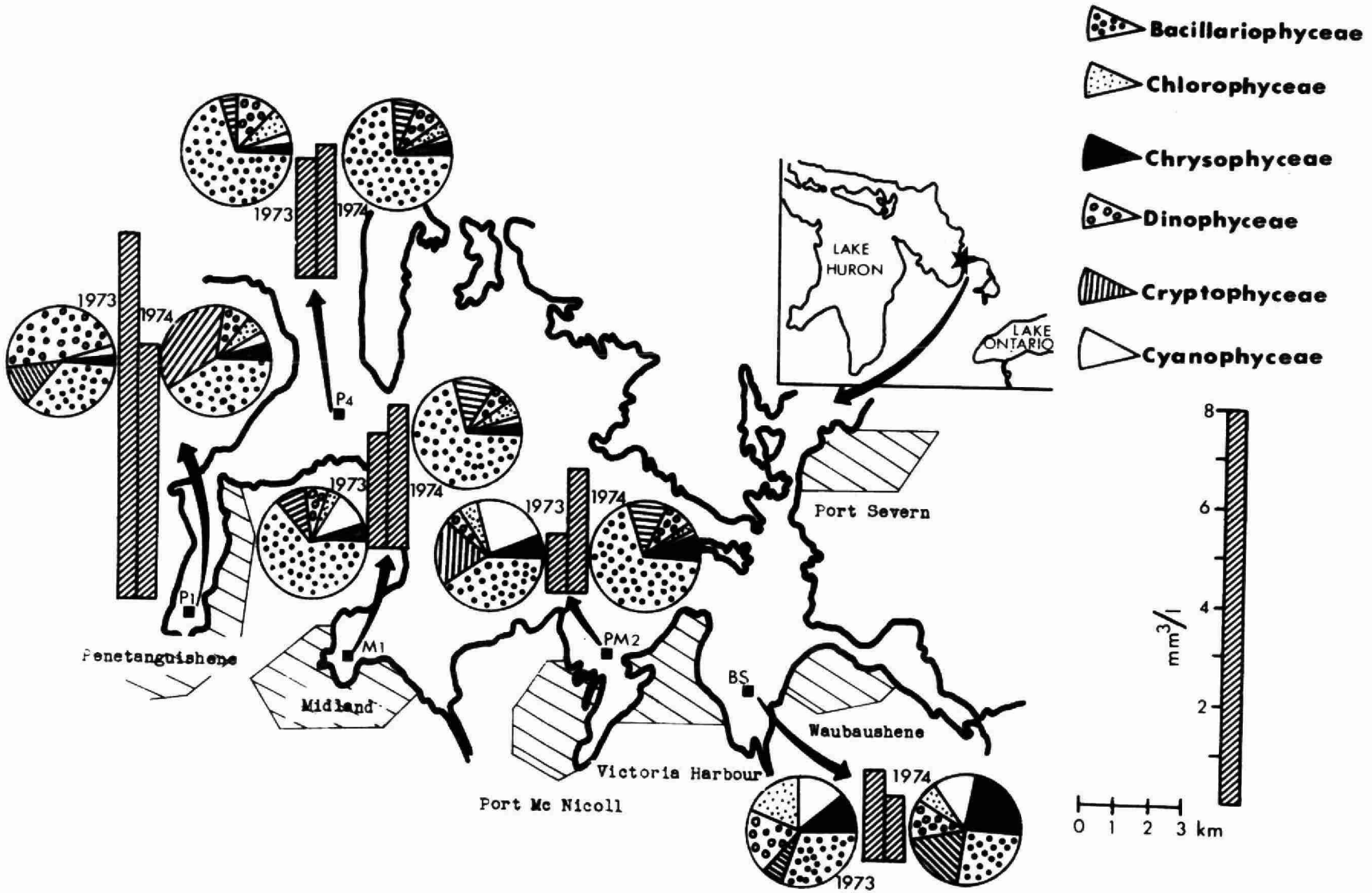

Figure 2 : Ice-free period mean phytoplankton biomass (mm^3/l or mg/l) and relative composition at the Georgian Bay inshore sampling locations during 1973 and 1974.

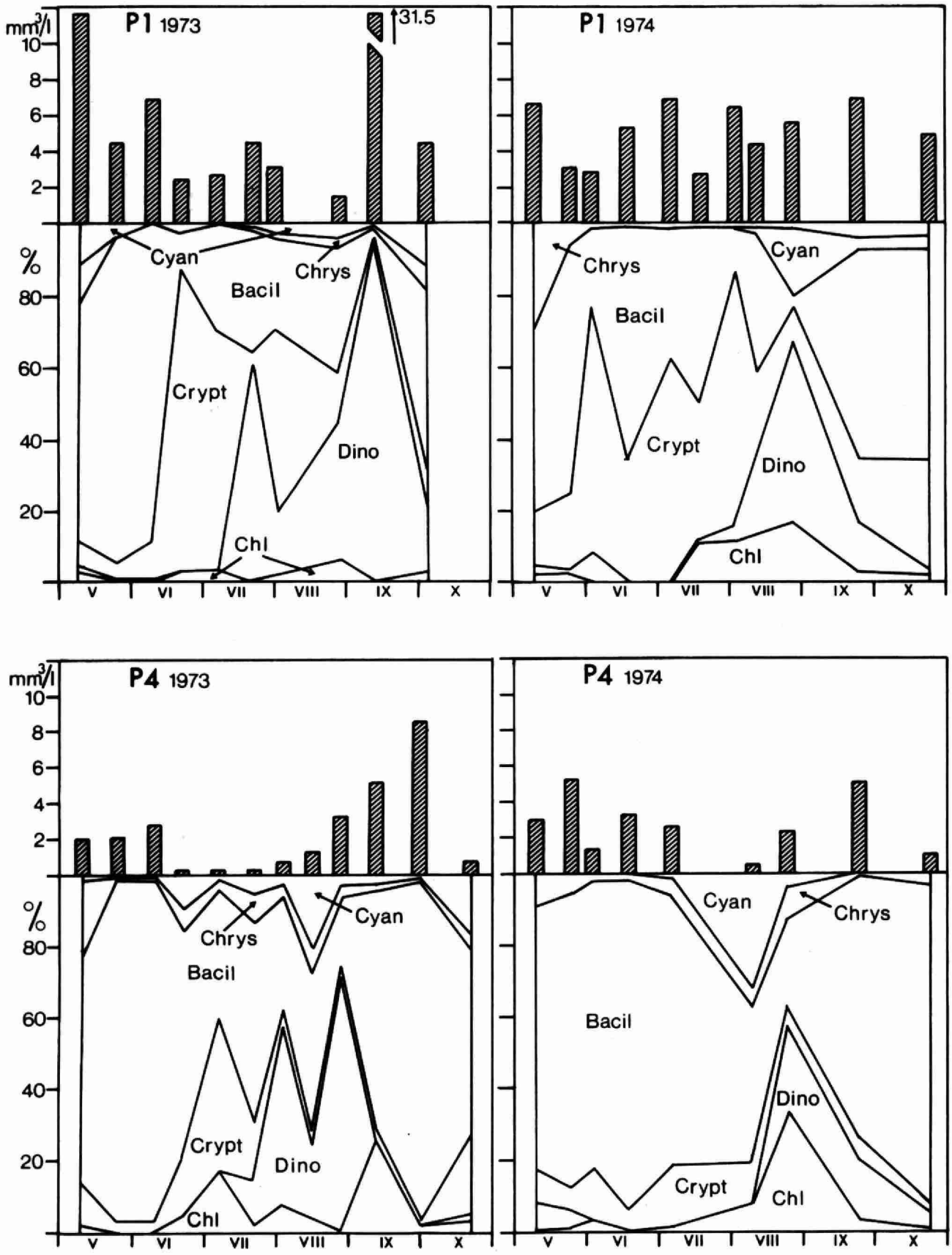

Figure 3 : Seasonal distribution of total phytoplankton biomass and percentage composition by class at Station P1 in Penetang Bay and P4, the outer northern-most sampling location during 1973 and 1974. Keyed as follows: Cyan - Cyanophyceae; Chrys - Chrysophyceae; Bacil - Bacillariophyceae; Crypt - Cryptophyceae; Dino - Dinophyceae; Chl - Chlorophyceae.

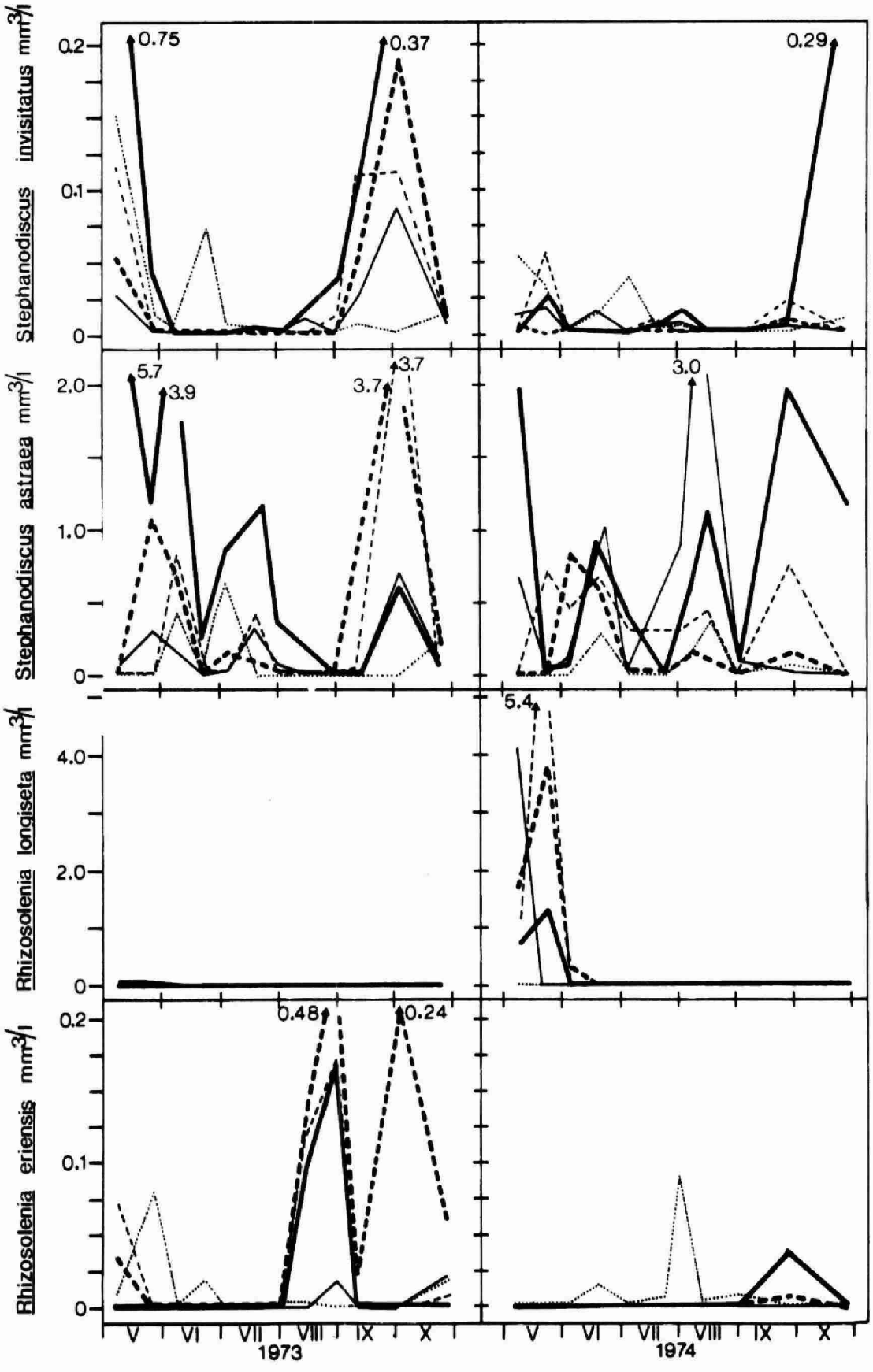

Figure 4: Seasonal distribution of Stephanodiscus invisitatus, S. astreae, Rhizolenia longiseta and R. eriensis (mm^3/l or mg/l) at the five inshore Georgian Bay locations. Keyed as follows: P1 (———); P4 (– – –); M1 (– – –); PM2 (———); BS (·····).

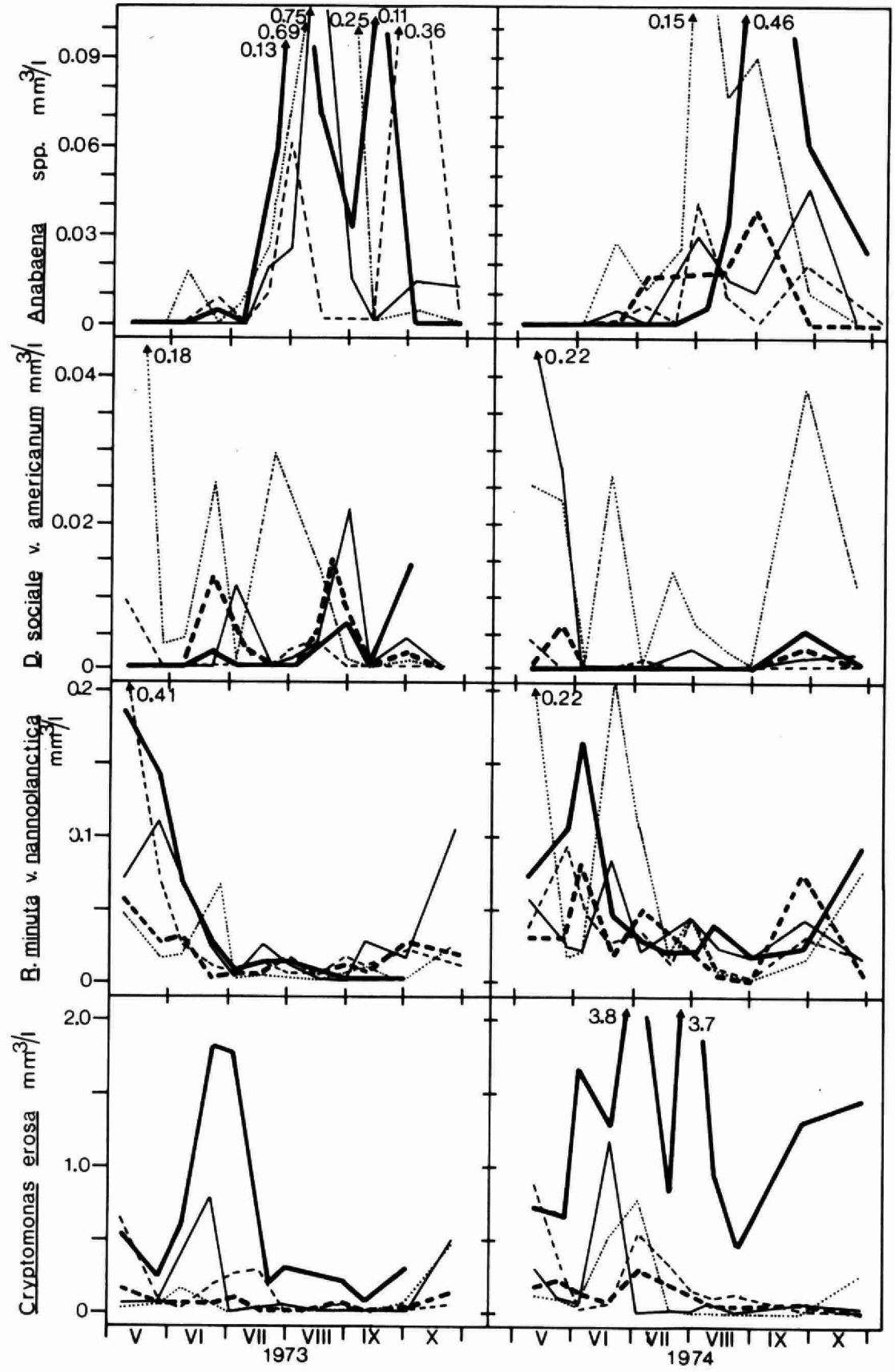

Figure 5: Seasonal distribution of Anabaena spp., Dinobryon sociale var. americanum, Rhodomonas minuta var. nannoplanctica, and Cryptomonas erosa (mm^3/l or mg/l) at the five inshore Georgian Bay locations. Keyed as follows: P1 (———); P4 (– – –); M1 (– – –); PM2 (———); BS (·····).

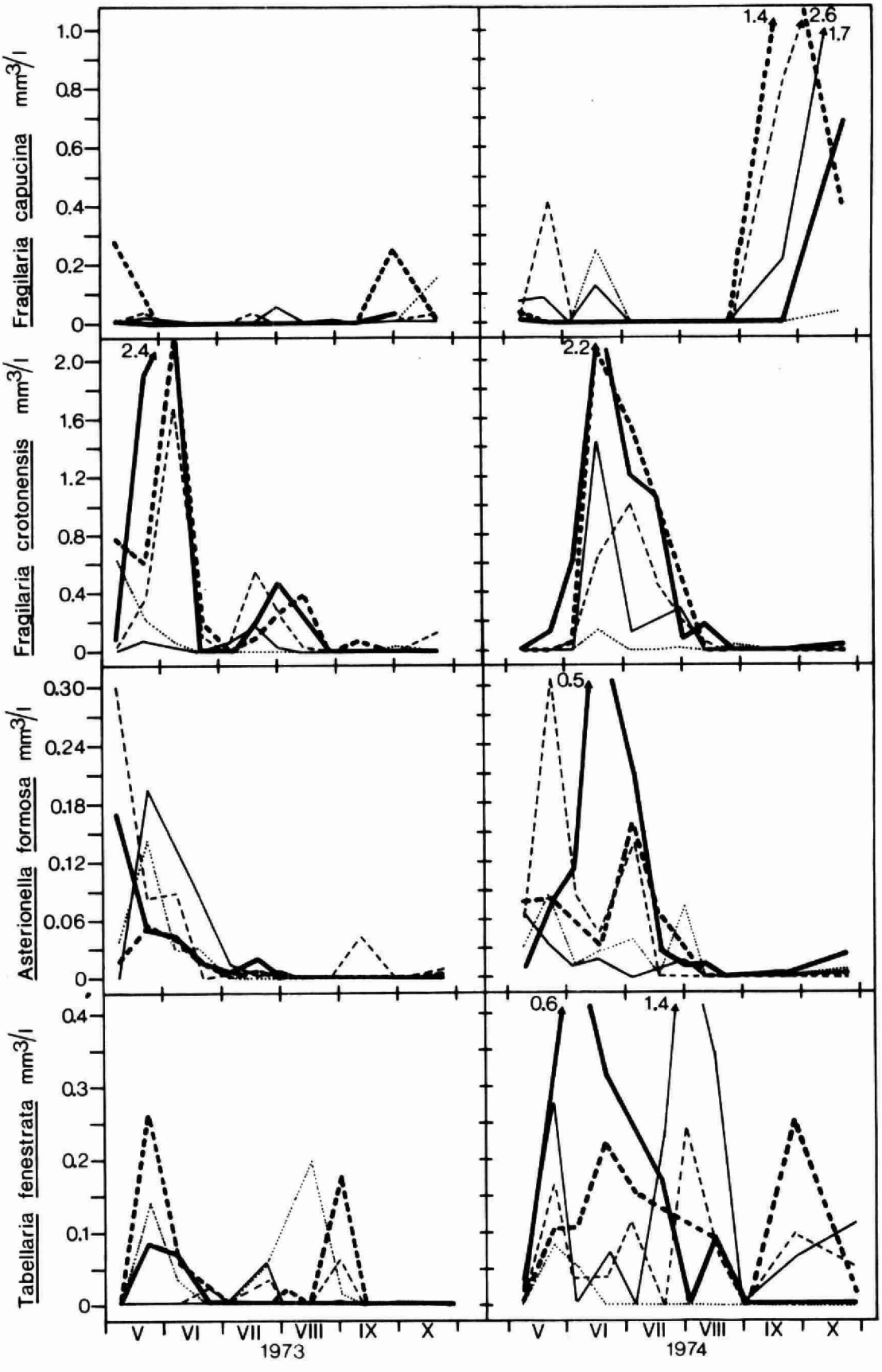

Figure 6: Seasonal distribution of Fragilaria capucina, F. crotonensis, Asterionella formosa and Tabellaria fenestrata (mm^3/l or mg/l) at the five inshore Georgian Bay locations. Key as follows: P1 (——); P4 (– – –); M1 (- - -); PM2 (——); BS (·····).

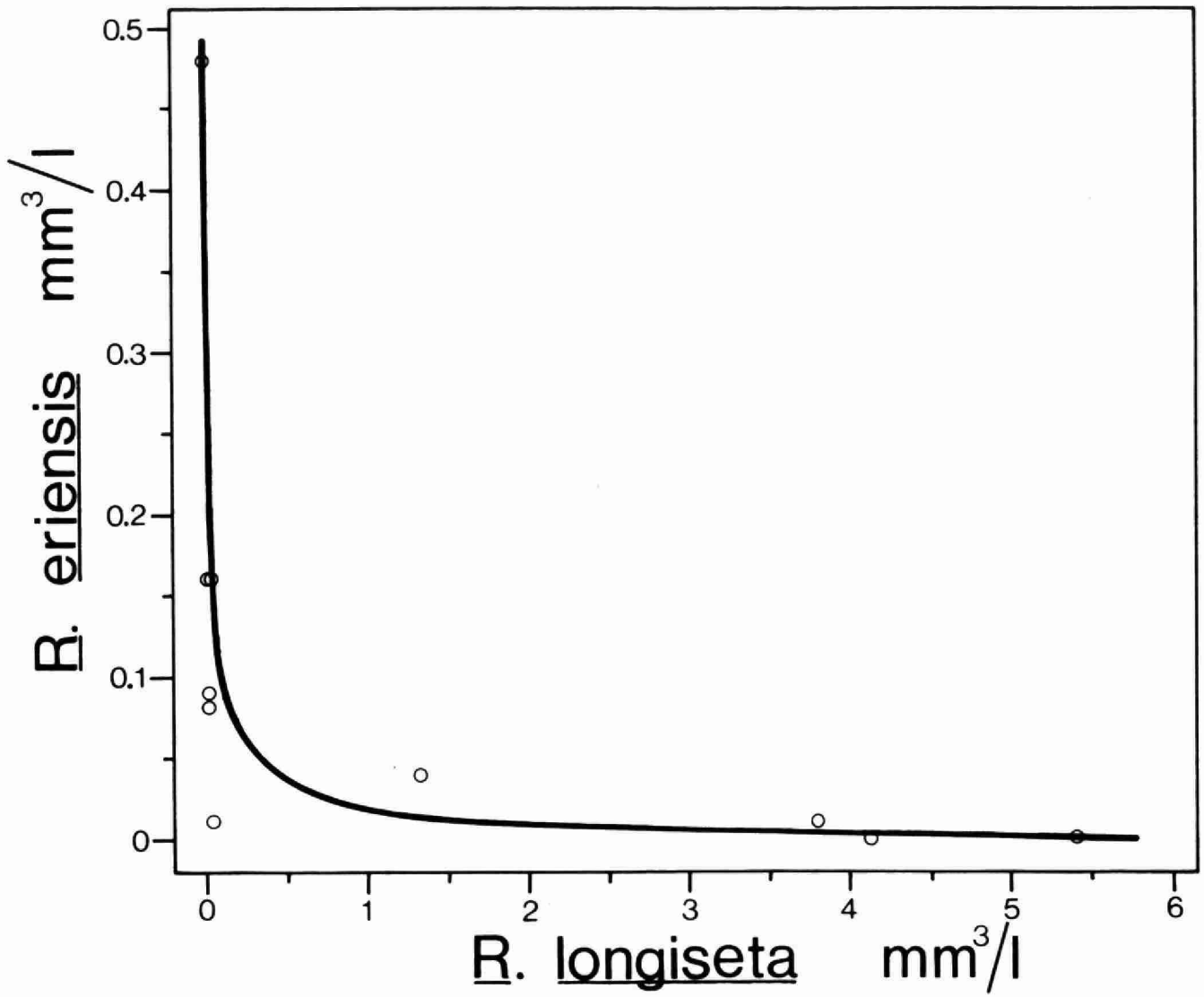

Figure 7: Maximum ice-free period biomass (mm^3/l or mg/l) of Rhizosolenia eriensis and R. longiseta at the five Georgian Bay inshore sampling locations during 1973 and 1974.

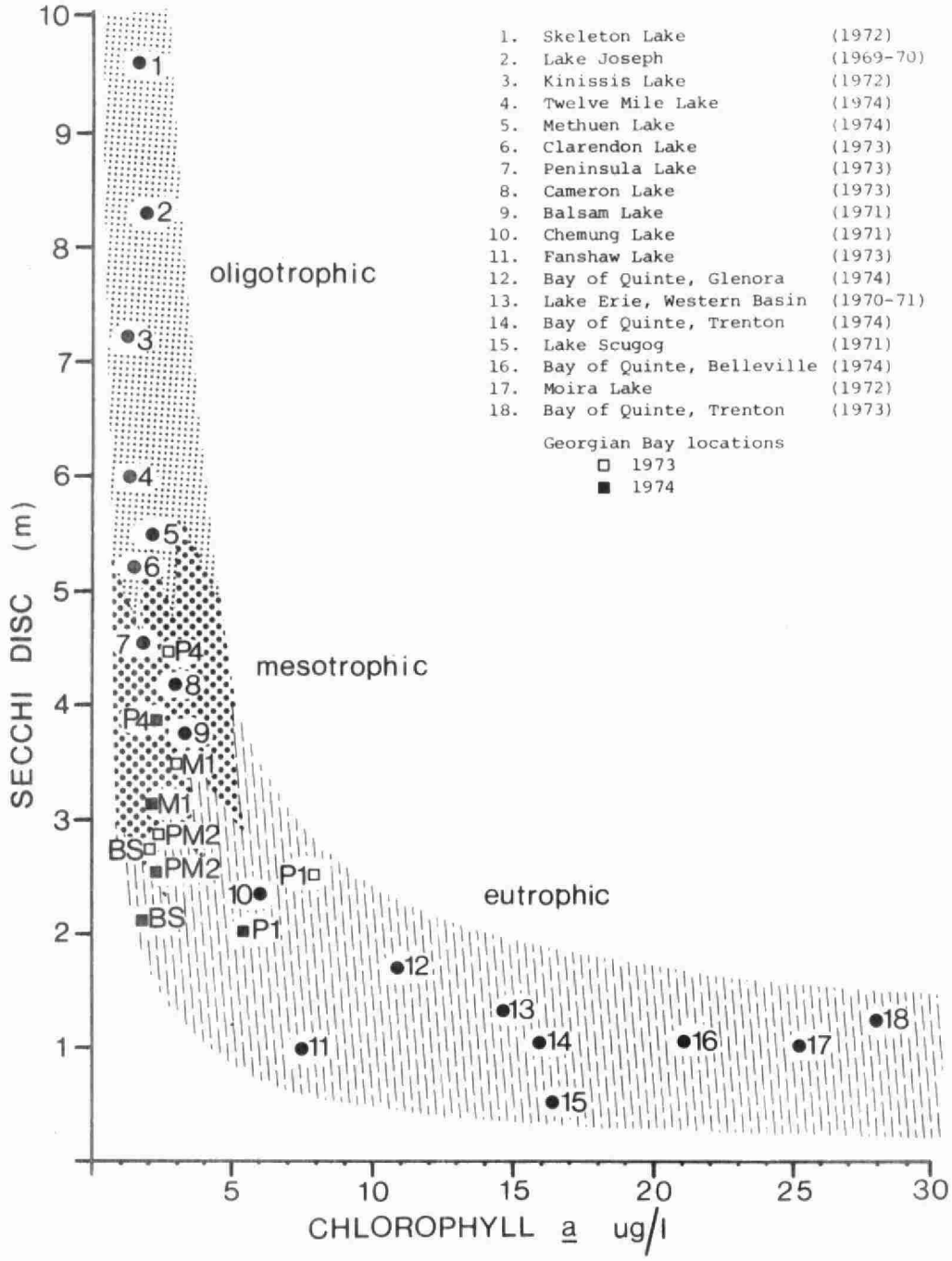

Figure 8: Relationship between chlorophyll a and Secchi disc developed from data on over 100 Ontario lakes and showing the trophic status of the inshore Georgian Bay locations relative to several other lakes in the province.

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APPENDIX 1 - Phytoplankton biomass (mm^3/l or mg/l) at five inshore sampling areas of Georgian Bay, 1973-1974. Keyed as follows: CHR - Chrysophyceae; CYAN - Cyanophyceae; CHL - Chlorophyceae; DINO - Dinophyceae; BACIL - Bacillariophyceae

Station	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	TOTAL	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	TOTAL
P1																		
	8/5/73	1.07	1.46	0.16	0.17	0.88	7.91	0	11.55	9/5/74	1.93	0	0.13	0.07	1.15	3.41	0	6.69
	24/5/73	0.13	0	0	0	0.30	4.07	0	4.51	23/5/74	0.17	0	0.07	0	0.85	2.57	0	3.66
	8/6/73	0.01	0	0	0.05	0.84	6.42	0	7.32	4/6/74	0.03	0	0	0.23	2.25	0.91	0	3.42
	22/6/73	0	0.01	0.09	0	2.02	0.30	0.01	2.42	18/6/74	0.02	0	0	0	1.68	3.66	0	5.36
	5/7/73	0.01	0	0.10	0	1.83	0.86	0	2.80	5/7/74	0.08	0	0	0	4.27	2.54	0	6.89
	20/7/73	0.08	0.06	0.02	2.57	0.23	1.44	0.01	4.41	18/7/74	0.05	0	0.30	0	0.96	1.27	0.01	2.59
	31/7/73	0.01	0.13	0.02	0.58	1.79	0.89	0	3.42	1/8/74	0.06	0.02	0.72	0.26	4.67	0.79	0	6.52
	27/8/73	0.02	0.07	0.11	0.68	0.26	0.62	0	1.75	12/8/74	0.02	0.04	0.50	0.87	1.09	1.56	0	4.07
	11/9/73	0.02	0.18	0.12	29.80	0.13	1.23	0	31.48	27/8/74	0.03	1.02	0.93	2.80	0.58	0.18	0	5.53
	1/10/73	0.16	0.62	0.16	0.80	0.49	2.55	0	4.78	25/9/74	0.13	0.21	0.17	0.84	1.41	3.95	0	6.72
										25/10/74	0.19	0.20	0.08	0.03	1.62	2.73	0	4.85
P4																		
	8/5/73	0.48	0.04	0.05	0	0.24	1.28	0	2.08	9/5/74	0.22	0	0.01	0.25	0.26	2.18	0	2.91
	24/5/73	0.02	0	0.01	0	0.08	2.06	0	2.17	23/5/74	0.25	0	0.02	0.31	0.31	4.24	0	5.13
	8/6/73	0.02	0.02	0	0	0.11	2.84	0	2.99	4/6/74	0.02	0	0.06	0	0.29	1.35	0	1.72
	22/6/73	0.02	0.03	0.01	0	0.06	0.24	0	0.37	18/6/74	0.03	0	0.02	0	0.21	3.02	0	3.28
	6/7/73	0.10	0	0.06	0	0.14	0.12	0	0.33	5/7/74	0.13	0.02	0.02	0	0.43	1.90	0	2.50
	20/7/73	0.03	0.02	0.01	0.05	0.06	0.22	0	0.38	12/8/74	0.02	0.22	0.06	0	0.08	0.31	0	0.69
	1/8/73	0.02	0.01	0.07	0.42	0.04	0.27	0	0.83	27/8/74	0.04	0.17	0.76	0.63	0.11	0.54	0	2.24
	14/8/73	0.08	0.25	0.05	0.26	0.06	0.56	0	1.27	25/9/74	0.03	0.01	0.10	0.93	0.17	3.75	0	4.99
	27/8/73	0.06	0.03	0.02	2.63	0.09	0.80	0	3.64	25/10/74	0.02	0	0.01	0.05	0.02	0.91	0	1.00
	11/9/73	0.03	0.11	1.51	0	0.11	3.81	0	5.56									
	1/10/73	0.06	0.03	0.19	0	0.10	8.40	0	8.78									
	23/10/73	0.03	0.13	0.03	0.01	0.17	0.42	0	0.78									

APPENDIX 1 - Phytoplankton biomass (mm^3/l or mg/l) at five inshore sampling areas of Georgian Bay, 1973-1974. Keyed as follows: CHR - Chrysophyceae; CYAN - Cyanophyceae; CHL - Chlorophyceae; DINO - Dinophyceae; BACIL - Bacillariophyceae

Station	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	TOTAL	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	TOTAL
M1																		
	8/5/73	0.75	1.65	0.07	0.03	1.07	0.91	0	4.48	9/5/74	0.36	0	0	0.03	0.96	1.67	0	3.03
	24/5/73	0	0	0	0.23	0.22	0.96	0	1.40	23/5/74	0.29	0	0.06	0	0.64	8.05	0	9.04
	7/6/73	0.03	0	0	0.09	0.13	2.69	0	2.94	5/6/74	0.01	0	0	0	0.09	0.65	0	0.75
	22/6/73	0.01	0.01	0.02	0	0.19	0.23	0	0.46	18/6/74	0	0	0	0	0.22	1.48	0	1.70
	5/7/73	0.05	0.01	0.01	0.02	0.36	0.04	0	0.49	5/7/74	0.04	0.01	0.01	0	0.91	1.59	0	2.56
	19/7/73	0.06	0.03	0.17	0	0.37	1.17	0	1.79	18/7/74	0.05	0	0.10	0.07	0.35	0.82	0	1.40
	31/7/73	0.02	0.06	0.02	0.02	0.02	0.27	0	0.42	31/7/74	0.04	0.05	0.05	0	0.40	0.80	0	1.35
	14/8/73	0.09	0.01	0.05	0.02	0.02	0.15	0	0.33	12/8/74	0.05	0.05	0.15	0.28	0.18	0.73	0	1.43
	27/8/73	0.09	0.33	0.06	1.33	0.12	0.86	0.01	2.80	27/8/74	0.02	0.15	1.21	0.68	0.16	0.01	0.02	2.24
	11/9/73	0.04	0.10	0.08	0.26	0.07	4.49	0.01	5.05	25/9/74	0.03	0.05	0.24	0.33	0.08	3.59	0	4.31
	1/10/73	0.07	0.52	0.16	0	0.03	5.16	0.02	5.97	25/10/74	0.07	0.01	0.01	0.24	0.08	3.12	0	3.51
	23/10/73	0.03	0.08	0.09	0	0.07	0.58	0	0.84									
PM2																		
	9/5/73	0.24	0.13	0.01	0	0.23	0.27	0	0.88	9/5/74	0.55	0.02	0.03	0.04	0.42	1.09	0	2.14
	24/5/73	0.04	0	0	0	0.28	0.65	0	0.98	22/5/74	0.23	0.07	0.03	0	0.24	4.90	0	5.47
	21/6/73	0.01	0	0.07	0	1.00	0.08	0	1.16	5/6/74	0.01	0	0.02	0	0.12	0.15	0	0.30
	5/7/73	0.23	0.01	0.01	0	0.15	0.11	0.01	0.51	18/6/74	0.03	0	0.01	0	1.77	2.80	0.01	4.61
	19/7/73	0.01	0.02	0.02	0	0.06	0.63	0	0.74	5/7/74	0.57	0	0.11	0	0.03	0.17	0	0.89
	31/7/73	0.02	0.03	0.02	0.15	0.09	0.19	0	0.49	31/7/74	0.03	0.04	0.07	0.02	0.07	2.65	0	2.88
	14/8/73	0.07	0.78	0.11	0.01	0.03	0.03	0	1.02	12/8/74	0.01	0.03	0.04	0.64	0.14	3.41	0	4.26
	28/8/73	0.08	0.05	0.07	0.34	0.04	0.24	0	0.81	27/8/74	0.03	0.02	0.17	0.57	0.02	0.09	0	0.90
	11/9/73	0.01	0.26	0.16	0	0.05	0.72	0	1.20	25/9/74	0.05	0.05	0.11	0.61	0.11	0.91	0	1.85
	1/10/73	0.09	0.09	0.07	0	0.02	2.25	0	2.52	22/10/74	0.09	0.02	0.01	0	0.05	2.03	0	2.19
	23/10/73	0.15	1.41	0.10	0	0.78	0.21	0	2.65									

APPENDIX 1 - Phytoplankton biomass (mm^3/l or mg/l) at five inshore sampling areas of Georgian Bay, 1973-1974. Keyed as follows: CHR - Chrysophyceae; CYAN - Cyanophyceae; CHL - Chlorophyceae; DINO - Dinophyceae; BACIL - Bacillariophyceae

Station	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	TOTAL	Date	CHR	CYAN	CHL	DINO	CRY	BACIL	EUG	Total
BS																		
	9/5/73	0.63	0.06	0.05	0	0.12	1.08	0	1.93	9/5/74	0.41	0	0.04	0.03	0.37	0.19	0	1.03
	25/5/73	0.43	0.03	0.02	0.05	0.13	0.76	0	1.41	22/5/74	0.14	0.07	0.01	0	0.14	0.27	0	0.62
	7/6/73	0.07	0.02	0.03	1.76	0.20	0.58	0	2.67	5/6/74	0.08	0.03	0.02	0.16	0.07	0.17	0	0.53
	21/6/73	0.16	0.04	2.79	0.31	0.17	0.43	0	3.89	18/6/74	0.16	0.04	0.07	0.10	1.02	1.10	0	2.49
	5/7/73	0.79	0.12	0.03	0.03	0.01	0.66	0	1.64	5/7/74	2.21	0.15	0.28	0.13	1.05	0.87	0	4.69
	19/7/73	0.08	0.04	0.03	0.02	0.05	0.11	0	0.32	18/7/74	0.80	0.24	0.16	0.04	0.07	0.02	0	1.32
	14/8/73	0.11	1.37	0.07	0.20	0.02	1.16	0.01	2.94	31/7/74	0.14	1.23	0.31	0.29	0.04	0.24	0	2.25
	27/8/73	0.04	0.34	0.07	0.10	0.03	0.03	0	0.60	12/8/74	0.09	0.10	0.04	0.19	0.03	0.39	0.01	0.84
	11/9/73	0.02	0.03	0.25	1.58	0.04	0.41	0	2.32	27/8/74	0.02	0.09	0.03	0.05	0.01	0.41	0	0.61
	1/10/73	0.03	0.12	0.01	0	0.06	0.52	0	0.75	25/9/74	0.15	0.02	0.01	0.02	0.04	0.10	0	0.34
	23/10/73	0.08	0.47	0.12	0	0.47	0.62	0	1.75	22/10/74	0.30	0.02	0.04	0	0.38	0.71	0	1.44

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